# Efficacy of herbicides against yellow nutsedge (*Cyperus esculentus*) plants originating from seeds

*Wirksamkeit von Herbiziden gegen aus Samen angezogene Erdmandelgraspflanzen (*Cyperus esculentus*)*

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## Abstract

Yellow nutsedge (*Cyperus esculentus*) is a troublesome weed. It reproduces and spreads mainly via tubers, but also viable seeds are produced. The seeds are very small and have little resources stored. The seedlings are very fragile and look like grasses (poaceae). We hypothesized that *C. esculentus* plants originating from seeds are more susceptible to herbicides than plants originating from tubers.

*Cyperus esculentus* plants grown from seeds in the greenhouse were treated with glyphosate, bentazone, bromoxynil, pelargonic acid and clethodim. Herbicide efficacy was rated and produced tubers were counted.

None of the treatments achieved full control. Four weeks after application a growth reduction of 84% was observed in the glyphosate treatment, whereas bentazone reduced growth by 34% compared to the control. In the other treatments, growth reduction was < 15%. In the glyphosate and bentazone treatment, considerably fewer tubers were produced than in the control.

Concluding, we could not confirm our hypothesis. Already 6 weeks after germination seedlings were well developed, tolerant to the sprayed herbicides, except for glyphosate and bentazone, and produced tubers. This implies, that already after a short time *Cyperus esculentus* stands originating from seeds pose the same problems as the ones originating from tubers.

**Keyword**: Bentazone, bromoxynil, chemical control, clethodim, glyphosate, pelargonic acid

## Zusammenfassung

Erdmandelgras (*Cyperus esculentus*) ist ein gefürchtetes Unkraut. Es vermehrt und breitet sich hauptsächlich über Knöllchen aus. Es werden aber auch keimfähige Samen gebildet. Die Samen sind klein und verfügen dementsprechend über wenig Speicherstoffe. Erdmandelgrassämlinge sind zart gebaut und ähneln Süßgräsern (Poaceae). Daher vermuteten wir, dass Erdmandelgrassämlingspflanzen sensibler auf Herbizide reagieren als aus Knöllchen gekeimte Pflanzen.

Im Gewächshaus wurden Erdmandelgraspflanzen aus Samen angezogen und mit Glyphosat, Bentazon, Bromoxynil, Pelargonsäure und Clethodim behandelt. Die Herbizidwirksamkeit wurde geschätzt und die Anzahl gebildeter Knöllchen bestimmt.

Kein Verfahren zeigte eine volle Wirkung. 4 Wochen nach Behandlung konnte eine Wuchsreduktion um 84 % und 34 % in den Verfahren Glyphosat resp. Bentazon im Vergleich zur unbehandelten Kontrolle beobachtet werden. Bei den anderen Verfahren lag die Wuchsreduktion unter 15 %. In den Verfahren Glyphosat und Bentazon wurden deutlich weniger Knöllchen gebildet als in der unbehandelten Kontrolle.

Zusammenfassend konnten wir unsere Hypothese nicht bestätigen. Bereits 6 Wochen nach Keimung waren die Sämlinge robust, vergleichsweise tolerant gegenüber den applizierten Herbiziden mit Ausnahme von Glyphosat und Bentazon und bildeten Knöllchen. Das bedeutet, dass bereits nach sehr kurzer Zeit aus Samen entstandene Erdmandelgrasnester die gleichen Probleme verursachen wie aus Knöllchen entstandene.

**Keywords**: Bentazon, Bromoxynil, chemische Bekämpfung, Clethodim, Glyphosat, Pelargonsäure

## Introduction

Yellow nutsedge (*Cyperus esculentus*) is a troublesome weed (Holm et al., 1991). The weed is difficult to control and it can cause high yield losses especially in vegetables (e.g. Keeley, 1987; Total et al., 2018). Yellow nutsedge reproduces and spreads via tubers in the soil; but also seeds, giving rise to viable seedlings, are produced under Swiss conditions (Schmitt, 1995; Keller et al., 2015). *Cyperus esculentus* seeds are rather small (1.1 to 1.6 mm long and 0.3 to 0.8 mm wide) (Tucker et al., 2002, cited in FOLLAK et al., 2016). Thus, they are even more easily spread than tubers e.g. with straw and hay being transported over large distances (LINGENFELTER and CURRAN, 2017).

There are many studies covering the efficacy of herbicides on *Cyperus esculentus* plants originating from tubers (FOLLAK et al., 2016). However, little is known about the sensitivity of *Cyperus esculentus* plants originating from seeds (BELL et al., 1962). As mentioned above, the seeds are very small and have little resources stored compared to the tubers (WEBSTER, 2003). Further, seedlings lack the typical robust yellow nutsedge habitus: They are very fragile and the leaves are tender and not waxy. Thus, at early growth stage the seedlings look like true grasses (poaceae) (KELLER et al., 2015). We hypothesized that *C. esculentus* plants originating from seeds are more susceptible to herbicides than plants originating from tubers.

In a greenhouse experiment, we determined the efficacy of different foliar active herbicides against *Cyperus esculentus* plants originating from seeds. Herbicides registered for use in vegetable crops or fallows in Switzerland were chosen (BLW, 2019). Of the tested herbicides, two herbicides are effective against "ordinary" *Cyperus esculentus* plants. In addition, a typical graminicide, a foliar active herbicide against broadleaved weeds and a natural non-selective herbicide were included in the experiment.

## Materials and Methods

*Cyperus esculentus* seeds collected in 2016 in Southern Switzerland were sown in the greenhouse in a shallow tray (0.28 m x 0.46 m x 0.7 m) in 2018. The substrate was a mixture of a sterilized arable sandy soil and Floradur A substrate (1:1). Sowing depth was 2 to 5 mm. After germination (2 weeks after sowing) 5 seedlings were transplanted to each pot (pot diameter 0.12 m, volume: 620 $cm^3$) containing Floradur A substrate. Average temperature in the greenhouse was 19 °C and relative humidity was 45%. If natural light conditions were below 15 kLux artificial light was provided.

The plants were treated 6 weeks after germination. Herbicide treatment was carried out with a precision application chamber (AVIKO Praha, Czech Republic) using a flat-fan band nozzle (Hypro E80 01). Spray amount was 400 l $ha^{-1}$. The following herbicide treatments were carried out:

- 1.1 kg $ha^{-1}$ Basagran SG (Leu + Gygax, SG, bentazone 870 g $kg^{-1}$)
- 2.5 L $ha^{-1}$ Roundup Max (Stähler, SL, glyphosate 450 g $L^{-1}$)
- 1 L $ha^{-1}$ Select (Stähler, EC, clethodim 240 g $L^{-1}$) with 2 L $ha^{-1}$ Zofal D (Stähler, EC, paraffin oil 830 g $L^{-1}$)
- 16 L $ha^{-1}$ Natrel (Stähler, EC, pelargonic acid 680 g $L^{-1}$)
- 1 L $ha^{-1}$ Xinca (Omya, SC, bromoxynil 402 g $L^{-1}$).

Thereafter, the treatments are referred to with the corresponding active substance name. An untreated control was included in the experiment. Per treatment, there were 9 pots (i.e. replicates). At the day of application, plants had on average 8 leaves, plant height was 0.14 m and secondary/daughter plants were present and even onset of tuber production was observed.

Efficacy was rated 2 and 4 weeks after application. Leaf necrosis (0 to 100%; 0%: no necrosis and 100%: leaves completely damaged *i.e.* dead) was estimated and general growth reduction was determined compared to the untreated control (0 to 100%; 0%: no effect, same size as untreated control and 100%: plant dead). Six weeks after application tubers were counted.

Statistical analysis was carried out in R studio (R version 3.5.3, 2019-03-11). A standard ANOVA and a Tukey HSD test were carried out for each rating day separately. Model assumptions were checked by diagnostic plots.

## Results

None of the treatments achieved full control (Tab. 1). Two weeks after application, some necrotic spots were also observed in the untreated control due to an unknown source of stress. 4 weeks after application no necrosis was observed anymore as many new leaves had developed. At the same time, a growth reduction of 84% was observed in the glyphosate treatment. Bentazone reduced growth by 34% as compared to the untreated control. The herbicide effect of bromoxynil, clethodim, pelargonic acid was transient and the plants had almost recovered 4 weeks after application (growth reduction < 15%). Consequently, the number of produced tubers was not significantly affected by these treatments as compared to the untreated control. There was considerable variability between pots within treatments (Tab. 2). For the bentazone treatment, the Tukey HSD test (p-value = 0.07) indicated a tendency towards less tuber production (6 tubers per pot) compared to the untreated control. Only in the glyphosate treatment, significantly less tubers were produced (1 tuber per pot) than in the untreated control (16 tubers per pot).

**Tab. 1** Herbicide efficacy 2 and 4 weeks after application against *C. esculentus*. At the day of application, plants were in the 8-leaf stage. Within columns, means followed by the same letter are not significantly different (p < 0.05) by Tukey HSD test. Significance: *** p-value < 0.001.

***Tab. 1*** *Herbizidwirksamkeit 2 und 4 Wochen nach der Applikation gegen C. esculentus. Am Tag der Applikation waren die Pflanzen im 8-Blattstadium. Mittelwerte innerhalb einer Kolonne mit demselben Buchstaben sind nicht signifikant verschieden (p-Wert < 0,05) ermittelt anhand des Tukey HSD Test. Signifikanz: *** p-Wert < 0,001.*

| | **2 weeks after application** | | **4 weeks after application** | |
|---|---|---|---|---|
| | **necrosis** | **growth reduction** | **necrosis** | **growth reduction** |
| | ---------------- in % ---------------- | | | |
| untreated | 10 | 0 d | 0 c | 0 c |
| bentazone | 24 | 52 bc | 21 ab | 34 b |
| glyphosate | 14 | 82 a | 24 a | 84 a |
| clethodim | 15 | 65 ab | 10 abc | 11 c |
| pelargonic acid | 14 | 43 c | 9 abc | 10 c |
| bromoxynil | 13 | 44 c | 5 bc | 0 c |
| significance | n.s | *** | *** | *** |

**Tab. 2** Newly produced tubers 6 weeks after application per pot. Per pot 5 *Cyperus esculentus* plants had been transplanted (mother plants). Within columns, means followed by the same letter are not significantly different (p < 0.05) by Tukey HSD test. Significance: *** p-value < 0.001. Min and max values are reported as a measure of variability.

***Tab. 2*** *Anzahl neu gebildeter Knöllchen 6 Wochen nach der Behandlung. Pro Topf waren 5 Erdmandelgraspflanzen pikiert worden (Mutterpflanzen). Mittelwerte innerhalb einer Kolonne mit demselben Buchstaben sind nicht signifikant verschieden. Signifikanz: *** p-Wert < 0,001. Die Min- und Max-Werte sind dargestellt, um die Variabilität innerhalb der Verfahren aufzuzeigen.*

| | **produced tubers per pot** | | |
|---|---|---|---|
| | **average** | **min** | **max** |
| untreated | 16 ab | 4 | 32 |
| bentazone | 6 bc | 3 | 11 |
| glyphosate | 1 c | 0 | 5 |
| clethodim | 20 a | 7 | 38 |
| pelargonic acid | 23 a | 8 | 37 |
| bromoxynil | 25 a | 16 | 37 |
| significance | *** | | |

## Discussion

*Cyperus esculentus* seeds have been described as an important mean to invade new areas and as a mean to adapt to the local environment (e.g. HOLM et al., 1991; TER BORG and SCHIPPERS, 1992; SCHMITT, 1995; WEBSTER, 2003). However, it is more often generally stated, that this pathway of dispersal is not important, negligible or not relevant (e.g. MULLIGAN and JUNKINS, 1976; STOLLER, 1981; STOLLER and SWEET 1987, SCHMITT and SAHLI, 1992; DODET et al., 2008; RIEMENS et al., 2008, FOLLAK, 2014). “Not relevant” in this context means, “it rarely occurs” (low probability). However, with large infested areas and high density *Cyperus esculentus* stands, even events with low probability such as seed germination and plant establishment will occur more often and thus, they become relevant.

In previous experiments, we could show that Swiss *Cyperus esculentus* seeds sown in spring germinated under field conditions if they were irrigated and did not experience competition. Within one season, new tubers were produced (KELLER et al., 2018). Such conditions (humid and bare soil) often occur in vegetable fields and there is no reason, why *Cyperus esculentus* seeds should not germinate and form new plant stands. In another experiment, seeds were sown in autumn. Several seeds germinated and plants established the following year and new tubers were produced (unpublished data).

Due to the aforementioned morphological differences, we assumed that young *Cyperus esculentus* plants originating from seeds would be more prone to herbicides commonly applied in vegetable crops or vegetable fallows. However, only glyphosate showed a rather good efficacy, whereas the efficacy of bentazone was intermediate. In both treatments, considerably fewer tubers were produced than in the untreated control. Both active substances are known to be effective against *Cyperus esculentus* plants originating from tubers (e.g. WEBSTER et al., 2008; ANONYMOUS, 2019). The poor efficacy of bromoxynil, clethodim and pelargonic acid found in the experiment was consistent with the efficacy reported for the 3 active substances against *C. esculentus* (WEBBER et al., 2014; ANONYMOUS, 2019). Hence, we could not confirm our hypothesis. Already 6 weeks after germination, seedlings were tolerant to 3 of the 5 applied herbicides. For the tested herbicides, the efficacy against *C. esculentus* plants originating from seeds was comparable to the reported efficacy against *C. esculentus* plants originating from tubers.

A next step would be to repeat this experiment with different seed batches. Different herbicide sensitivities of *C. esculentus* clones have been already reported (e.g. DE CAUVER et al., 2017). In our experiment, the efficacy of only a few herbicides was tested on one *C. esculentus* seed batch. Nevertheless our findings imply, that already after a short period *C. esculentus* stands originating from seeds pose the same problems as the ones originating from tubers. In addition, each *C. esculentus* plant originating from a seed is in itself a new clone with new gene combinations, and thus potentially more vigorous or more tolerant to herbicides than its parents.

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